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Zooplankton in relation to herring in the Norwegian Sea, June 1959

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CONTENTS

Introduction 5
Material and methods 5
Quantitative distribution of zooplankton 7
The composition of the zooplankton 9
Stage composition of *Calanus finmarchicus* 10
Plankton and herring 11
Summary 13
References 13

INTRODUCTION

Since GRAN (1902) first started plankton investigations in the Norwegian Sea, the zooplankton of this area has been thoroughly investigated by several scientists. WIBORG (1954) gives a comprehensive list of papers concerning plankton and hydrography in the Norwegian Sea.

At the meeting of the International Council for the Exploration of the Sea in Amsterdam 1951, Danish, Icelandic and Norwegian scientists decided to cooperate on the exploration of the Atlanto-Scandian herring during its feeding period in the Norwegian Sea. In 1957 Soviet scientists joined the investigations, which included studies of the herring concentrations, the hydrography and the plankton. Below are presented the results of the zooplankton investigations included in the Norwegian part of the programme in June 1959.

The present paper has been made possible by the courtesy of Messrs. EGGVIN, DEVOLD and BERGE, who kindly placed their observations on salinities, herring concentrations and transparencies of the seawater at my disposal.

Thanks are also due to stud.real. OTTO GRAHL-NIELSEN and stud. real. IVAR STEINE for valuable technical assistance.

MATERIAL AND METHODS

During a cruise with RV "Johan Hjort" from 2. to 28. June 1959 zooplankton was collected at 121 stations in the Norwegian Sea (Fig. 1). Vertical hauls were made from 50 to 0 m and from 100 to 0 m. Most of the material was obtained with a Nansen-net (diameter 72 cm and silk No. 8), but in areas with great amounts of phytoplankton a similar net with a coarser silk (No. 0) was used. A number of stations in the central part of the area had to be omitted due to rough weather.

On board the ship the volumes of the samples were measured by the method of displacement and the most important species noted. The

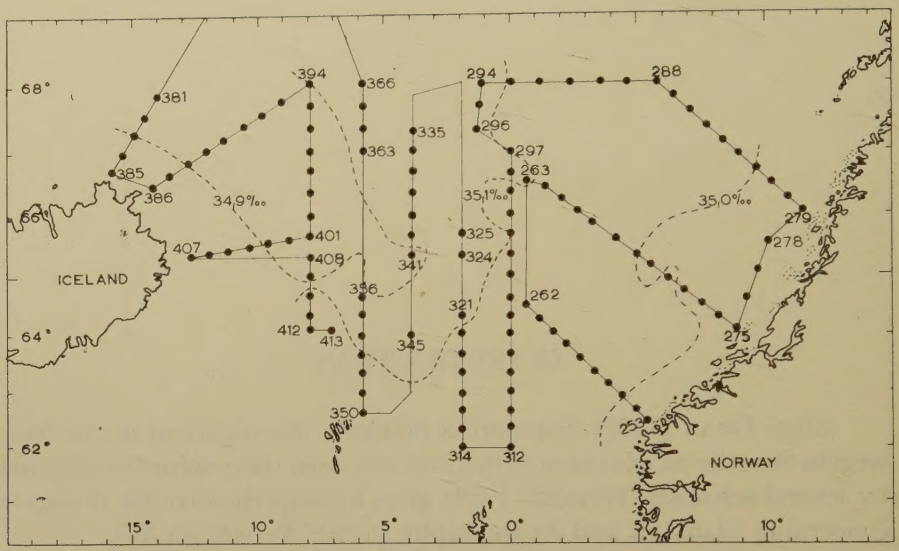

Fig. 1. Stations and salinities in the Norwegian Sea, June 1959.

stage composition of *Calanus finmarchicus* in the samples was determined ashore. The samples were preserved in 4—8 % formalin.

The term "mixed waters" has been used by different scientists working on material from the Norwegian Sea. In the present paper this term has been used in order to characterize the water masses formed by mixing of the Atlantic waters and the East Icelandic current, limited by the isohalines 34.9 $^0/_{00}$ and 35.1 $^0/_{00}$ (Fig. 1).

QUANTITATIVE DISTRIBUTION OF THE ZOOPLANKTON

Fig. 2 shows the volume of zooplankton in ml/m^3 for the 50—0 m samples. The greatest concentrations occurred in the border area between the Atlantic waters and the Norwegian coastal waters along the slope of the continental shelf, from about 64° N to 67° N. The plankton on the Norwegian coastal banks was, however, very scanty.

In the Atlantic waters the concentrations of zooplankton was somewhat higher than in the mixed waters. In the southern part of the Norwegian Sea (north of the Faroes) Hansen (1959) found the mixed waters to be the richest of the water masses in June.

The East-Icelandic current appeared to be the poorest of the water masses investigated. This is in good accordance with Hansen (1959),

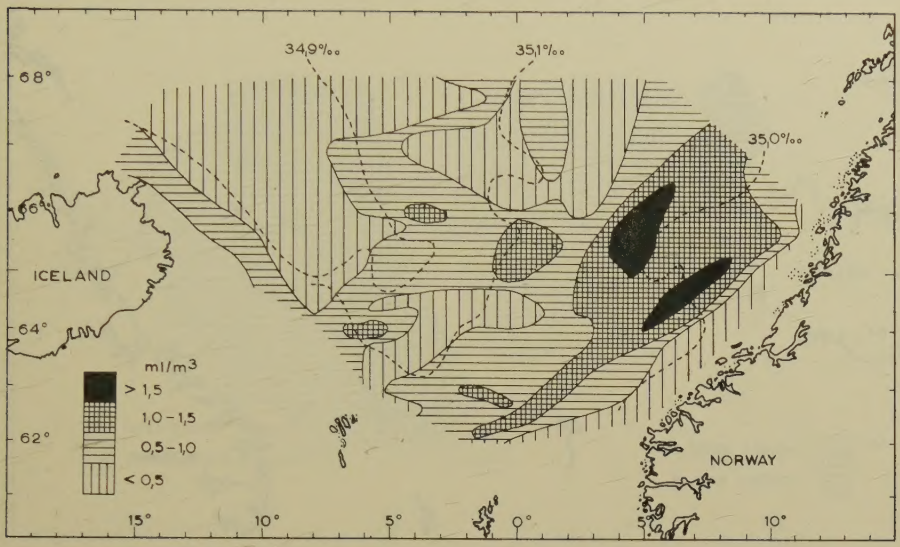

Fig. 2. Quantitative distribution of zooplankton in ml/m³.

while Pavshtiks (1956, 1960) in June found higher concentrations in the East-Icelandic current than in the mixed waters. Below are given the mean zooplankton-volumes in ml of the 50—0 m hauls in the five different water masses.

Norwegian coastal waters	Atlantic waters	mixed waters	East-Icelandic current	Irminger current
14.4	12.7	10.3	4.3	12.1

The main part of the plankton was concentrated in the upper 50 m, except 17 stations where the volumes were higher in the 100—50 m layer. At 22 % of the stations the volumes of the 50—0 m samples were higher than in the 100—0 m samples. This may partly be due to the patchiness of plankton. However, in rough weather it was impossible to keep the wire in a vertical position during hauling, and consequently the net was sometimes towed horizontally along the surface for several metres towards the ship. This may have caused considerable sampling errors as the plankton was probably abundant near the surface.

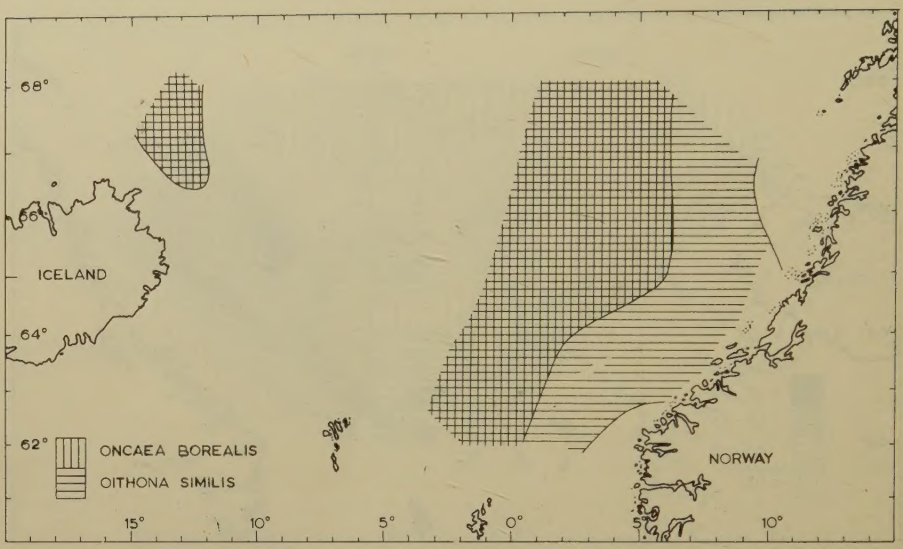

Fig. 3. Distribution of *Oncaea borealis* and *Oithona similis*.

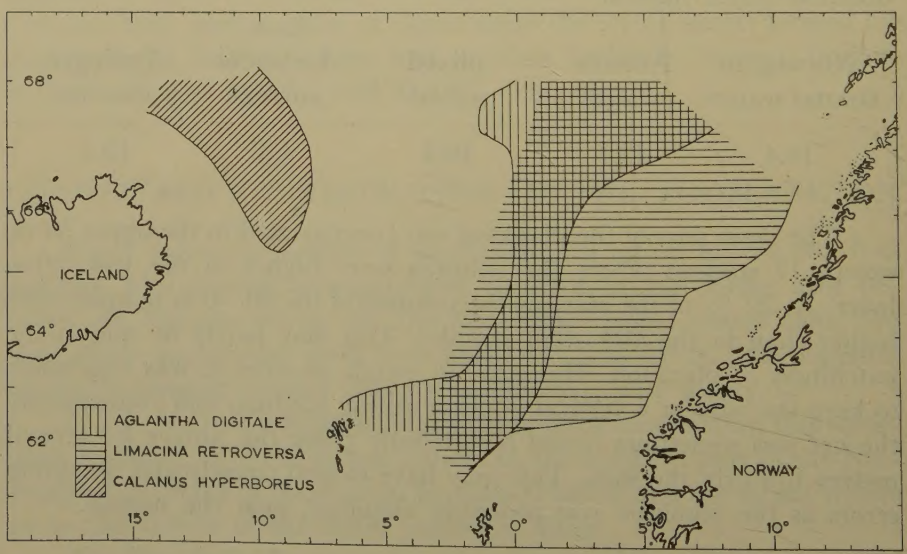

Fig. 4. Distribution of *Aglantha digitale*, *Limacina retroversa* and *Calanus hyperboreus*.

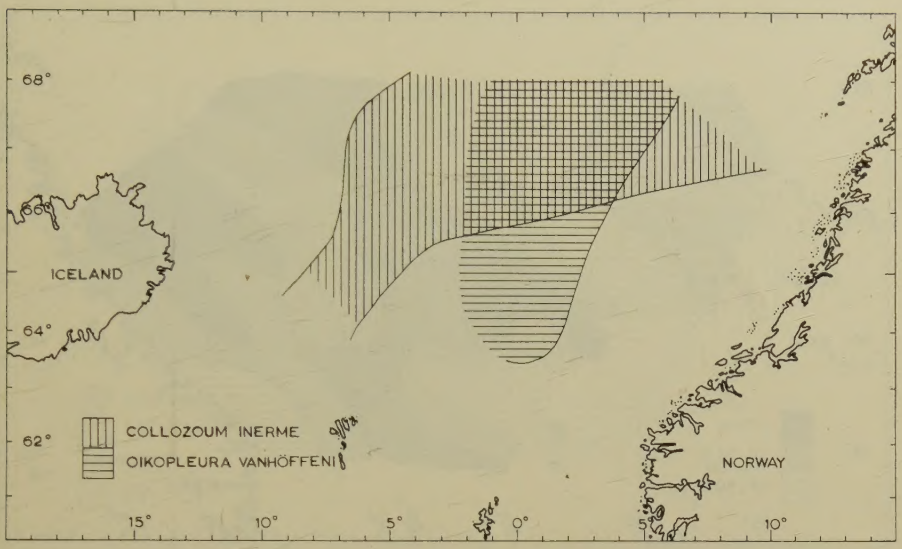

Fig. 5. Distribution of *Collozoum inerme* and *Oikopleura vanhøffeni*.

THE COMPOSITION OF THE ZOOPLANKTON

Calanus finmarchicus was the dominating copepod except at a few stations to the north-east of Iceland, where *Calanus hyperboreus* and *Metridia longa* were numerous. The zooplankton of the mixed waters consisted nearly entirely of *Calanus finmarchicus*.

Oncaea borealis and *Oithona similis* were common in the Atlantic waters (Fig. 3) and at a few stations to the north-east of Iceland. This distribution of *Oncaea borealis* is unusual, as the species according to JESPERSEN (1939) has its main distribution in Arctic waters. In the Norwegian Sea, *O. borealis* was found in the East-Icelandic current and in the mixed waters by WIBORG (1954, 1955) and HANSEN (1959). At the weather station M at 66° N and 2° E, ØSTVEDT (1955) found the species mainly in the cold water below 600 m.

Pseudocalanus elongatus, *Themisto abyssorum*, and larvae of euphausids occurred all over the area investigated, while adult euphausids (*Thysanoessa longicaudata*) were found only in the East-Icelandic current.

Common in the Atlantic waters were *Aglantha digitale*, *Limacina retroversa* and *Oikopleura vanhöffeni*, while *Collozoum inerme* occurred both in Atlantic and mixed waters (Figs. 4 and 5).

A few larvae of *Sebastes marinus* and *Gadus esmarki* were found at Storegga off the west coast of Norway.

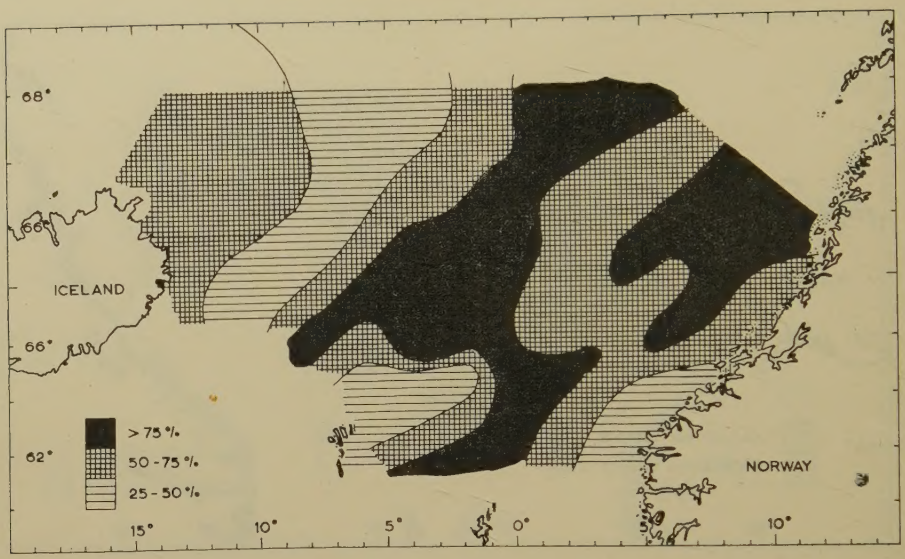

Fig. 6. Percentage distribution of the copepodite stages IV and V of *Canalus finmarchicus*.

Considering the distribution of *Oncaea borealis*, *Oithona similis*, *Limacina retroversa* and *Oikopleura vanhöffeni* (Figs. 3, 4 and 5) the scarcity of stations in the central part of the area investigated reduces the reliability of the western border of their distribution.

STAGE COMPOSITION OF CALANUS FINMARCHICUS

Fig. 7 shows the distribution of the copepodite stages I—III and adults, Fig. 6 the stages IV and V.

A high percentage of the stages IV and V was found in extensive areas of the Norwegian coastal waters, the Atlantic waters and the mixed waters.

According to HANSEN (1959) *Calanus finmarchicus* has only one generation a year in Faroe waters. Fig. 7 shows a rather high percentage of the stages I—III north of the Faroes, which might indicate a second generation. However, as suggested by WIBORG (1954), *C. finmarchicus* spawned in the Atlantic Ocean may be brought into the Norwegian Sea by the Atlantic current.

In the Norwegian coastal waters off Møre, adults of *C. finmarchicus* were found rather frequently, which might indicate a prespawning condition. According to WIBORG (1954) the second spawning of *C. finmarchicus* at Ona (Møre) took place in early June.

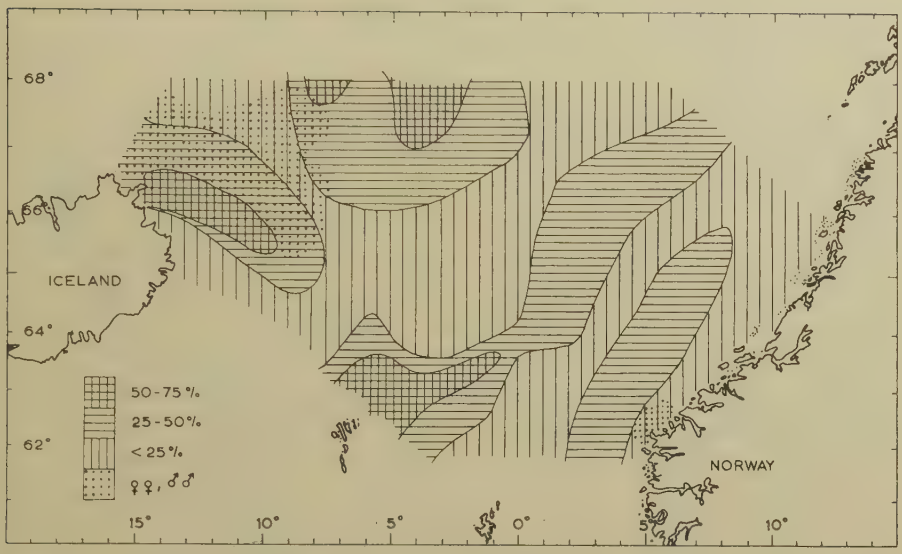

Fig. 7. Percentage distribution of the copepodite stages I—III and adults of *Calanus finmarchicus*.

The greatest concentrations of adult *C. finmarchicus* occurred in the cold water of the East-Icelandic current, while the stages I—III were scarce. This may indicate a prespawning condition, but as the net used in this area had a rather coarsemeshed silk, any nauplii and stage I copepodites actually present may have been lost.

PLANKTON AND HERRING

As shown by Berge (1958, 1959) the transparency of the sea water in the open sea is mainly influenced by the density of phytoplankton. During a cruise with RV "Johan Hjort" in the Norwegian Sea in June 1959 the transparency at 5 m depth was recorded continuously with the 'transparencymeter' (Berge 1959). The relative units of transparency together with the herring concentrations are shown in Fig. 8.

Henderson, Lucas and Fraser (1936) stated that the herring as a rule seem to avoid dense concentrations of phytoplankton, and Pavshtiks (1960) found herring in areas with diatoms but not in areas with dense concentrations of *Phaeocystis*. These results seem to be supported by Fig. 8, where the high numbers of the relative units of transparency in the East Icelandic current are caused by *Phaeocystis*.

Lucas (1936) and Henderson (1936) found a positive correlation between herring and zooplankton. So did Ptshelkina (1939) in the

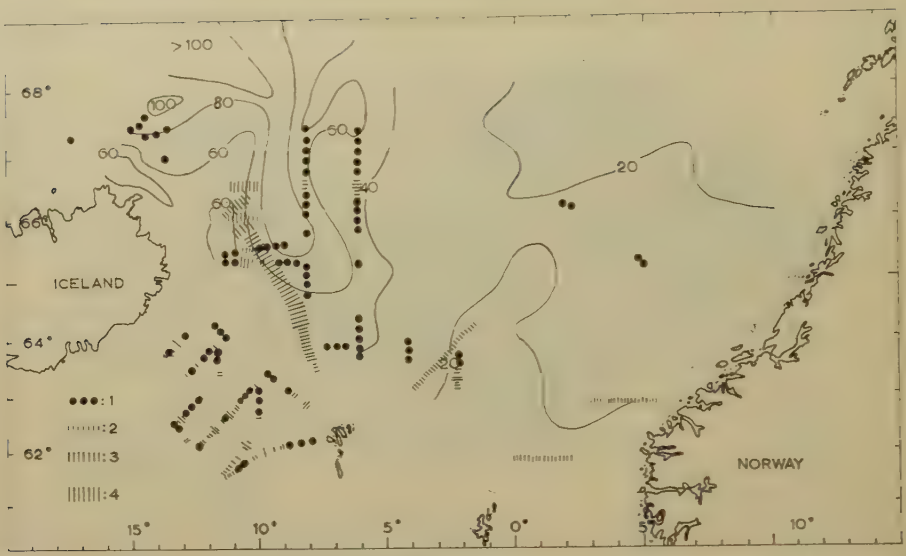

Fig. 8. Transparency of sea water in relative units (from 20 to 100) and herring concentrations. 1: very scarce, 2: scarce, 3: good, 4: very good.

Barents Sea in June and July, when the *Calanus*-population was developing, but in August there was a negative correlation. The latter phenomenon was explained by suggesting that the herring had grazed down the *Calanus*-population.

In the present material no positive correlation between herring and zooplankton can be traced. In the areas richest in zooplankton the herring was very scarce. According to Fig. 8 the herring in June was concentrated in mixed waters along the south-western border of the East-Icelandic current. As shown in Fig. 2 the mixed waters were not very rich in zooplankton, but the plankton consisted of later stages of *Calanus finmarchicus*, which might indicate that a reduction of the stock had taken place. The negative correlation between herring and zooplankton may thus be explained according to PTSHELKINA's theory.

PAVSHTIKS (1958) stated that the herring follows the shift of the spawning of *C. finmarchicus*, starting feeding in the Atlantic waters, continuing into the mixed waters and moving at last into the cold water of the East-Icelandic current.

LUCAS and HENDERSON (1936) found that the herring seems to avoid dense concentrations of *Limacina* and (l.c. p. 301) '"small" jellyfish and particularly "small white" jellyfish'. Figs. 4 and 5 show that the herring was very scarce in areas with *Limacina retroversa* and *Aglantha digitale*, but according to RUDAKOVA (1956) both species may occur in stomachs of herring in spring and summer.

SUMMARY

1. During a cruise with RV "Johan Hjort" from 2. to 28. June 1959 zooplankton was collected at 121 stations in the Norwegian Sea.
2. The zooplankton was most abundant in the border area between Atlantic waters and Norwegian coastal waters, and scanty in the cold water of the East-Icelandic current.
3. *Calanus finmarchicus* was the dominating copepod, except at a few stations off Iceland. *Pseudocalanus elongatus*, *Themisto abyssorum* and larval stages of euphausids were common all over the area investigated. In the Atlantic waters *Oithona similis*, *Oncaea borealis*, *Aglantha digitale* and *Oikopleura vanhöffeni* were common, while *Collozoum inerme* also occurred in mixed waters. Larvae of *Sebastes marinus* and *Gadus esmarki* were found at Storegga off the west coast of Norway.
4. Both in Norwegian coastal waters, Atlantic waters, mixed waters and in the Irminger current the copepodite stages IV and V of *Calanus finmarchicus* dominated. In the East-Icelandic current and also off Møre a high percentage of adults occurred.
5. The relation between herring, phytoplankton and zooplankton is discussed.

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